Ohio State University Working Papers in Linguistics 38 (88-104)

VCV Coarticulation in Arabic

Lutfi Hussein

Ohio State University

Abstract: Vowel-to-vowel coarticulation in VCV utterances has been the subject of several studies. Öhman (1966) found that vowels in VCV utterances in English and Swedish have trans-consonantal effects on one another. He also found some evidence suggesting that secondary articulation features like palatalization in Russian block coarticulation. Action theorists, such as Fowler (1983), explain V-to-V coarticulation in terms of universal principles of speech timing; that is, they claim that vowels in speech production are underlyingly overlapping and consonants ride on top of the vowels. This suggestion implies that intervocalic consonants, regardless of whether they have secondary articulation features, do not block coarticulation. Keating (1985), on the other hand, explains it in terms of autosegmental phonology. She places the features for vowels and consonants on two separate tiers, and leaves consonant features unspecified for vowel features, so that V-to-V coarticulation is an interpolation between vowel targets. Keating's model implies that consonants that have secondary articulation (i.e. vowel features) must block coarticulation. 72 VCV utterances which include combinations of all vowels in Standard Arabic and a set of four pharyngealized consonants and their nonpharyngealized counterparts have been acoustically analyzed to assess the validity of the two models. The final analysis of the data indicates that V-to-V coarticulation is not as simple as either of the two models claims it to be. Several other factors such as the identity of the vowel included in the sequence, the speaker, and the direction of coarticulation (anticipatory versus carryover) have proven to be crucially important in accounting for V-to-V coarticulation.

1. Introduction

Vowel-to-vowel coarticulation in VCV utterances has been the subject of several acoustical and perceptual studies during the last two decades (Öhman 1966; Purcell 1979; Fowler 1983; Keating 1985; Recasens 1985, 1986). Öhman (1966), a pioneer in investigating vowel-to-vowel coarticulation, found that vowels in Swedish and English exhibit systematic coarticulatory effects on one another across intervocalic stops in VCV utterances. He also found that neither fricatives in Swedish and English nor palatalized stops in Russian permit similar systematic coarticulatory effects in VCV utterances. This outcome had been a primary incentive for the many studies and models that followed, among which the most prominent are those of Fowler (1983) and Keating (1985).

Fowler (1983) explains coarticulation in terms of timing. She claims that vowels are underlyingly overlapping in speech production and consonants are superimposed on the vowels. Thus, speech is primarily a continuous production of vowels. The following figures, where **1A** is taken directly from Fowler (1983), elaborate Fowler's model.

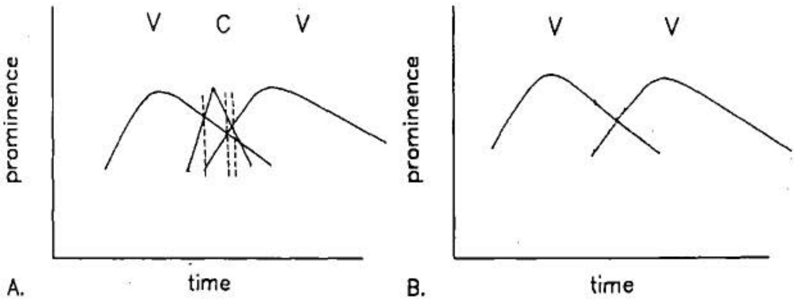


Fig. 1: Fowler's model of coarticulation.

According to this model, V-to-V coarticulation occurs because there is no temporal separation of vowels in either **1A,** where the intervocalic consonant is "superimposed" on the vowels, or 1B where there is no intervocalic consonant. This model implies that intervocalic consonants, regardless of what phonological features they may have, do not block V-to-V coarticulation. Such a claim obviously contradicts Öhman's findings which indicate that some consonant classes such as fricatives in English and Swedish and palatalized consonants in Russian block coarticulation, and Purcell's (1979) finding, which is derived from an extensive study on palatalization, that palatalized consonants in Russian indeed block coarticulation.

Keating, by contrast, explains coarticulation in terms of feature association patterns in autosegmental phonology. See Figure 2 below for illustration. She places the features for vowels and consonants on two separate tiers, and leaves consonants unspecified for vowel features, so that V-to-V coarticulation is an interpolation between vowel targets. This model claims that intervocalic consonants that use the vowel tiers in the production of consonants with secondary articulations such as palatalized consonants in Russian, velarized /ɫ/ in Catalan, pharyngealized consonants in Arabic, etc. should block V-to-V coarticulation in VCV sequences. It also implies that consonants with no vowel features should not block coarticulation. This model, though it elegantly accounts for the behavior of palatalized consonants in Russian, lacks the explanatory power to account for the behavior of intervocalic fricatives in English and Swedish as reported by Öhman.

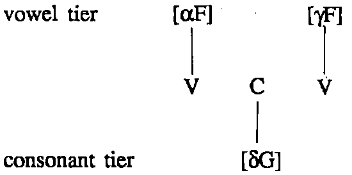


Fig. 2: Keating's model of coarticulation.

In this study I acoustically analyze a set of VCV utterances from Arabic to further assess the validity of the two models. Arabic has a distinctive opposition between a set of four pharyngealized consonants[1] and four nonpharyngealized counterparts. Two of these are pharyngealized stops (i.e., /t̲/[2] and /d̲/) and two are fricatives (i.e., /s̲/ and /ð̲/). The data used in this study include all the pharyngealized consonants and their plain counterparts uttered in the context of all vowels, of which there are only three in Arabic, namely /i/, /a/, and /u/. With such characteristics, Arabic makes a potentially good example to test the two models sketched above. According to Fowler's model, Arabic should exhibit V-to-V coarticulatory effects in VCV utterances regardless of the identity of the intervocalic consonant. In other words, there should be no consonants, or classes of consonants, that block V-to-V coarticulation in Arabic. Keating's model, on the other hand, predicts that Arabic should only exhibit V-to-V coarticulation when the intervocalic consonant is nonpharyngealized. It places no constraints on whether any nonpharyngealized consonants are likely to block coarticulation, as is the case with fricatives in English and Swedish.

Another related issue that will be discussed in this paper is whether coarticulatory effects are restricted to formant transitions or extend into the steady state. Early acoustic studies on coarticulation reported that coarticulatory effects in VCV utterances are limited to the transitions of the vowels (Öhman 1966). More recent studies have shown that transconsonantal coarticulatory effects can extend into the steady state of the adjacent vowels as well as the transitions (Manuel and Krakow 1984).

---

[1] Several terms such as *emphatic* (Jakobson 1957; Ali and Daniloff 1972; Bonnot 1977 and 1979), *mufaxxama* (Jakobson 1957), *velarization* (Obrecht 1961), and *pharyngealization* (Ali and Daniloff 1972; Ghazeli 1977; Card 1983) have been used to describe the distinctive opposition among a set of consonants in Arabic. According to cinefluorographic studies, none of these terms is exclusively accurate in describing the distinction. All these terms, however, have been used interchangeably by many linguists. In this study I will, following some tradition, be using the term *pharyngealization* to denote this distinction though the production process for these sounds involves more than just pharyngealization.

[2] Underlining is used in this study to denote pharyngealization. Thus /s/ is a plain dental fricative in Arabic, but /s̲/ is a pharyngealized dental fricative.

The two models mentioned above present different views as to whether the steady state should show coarticulatory effects or not. According to Keating, coarticulation is an interpolation between two targets; a claim which implies that coarticulatory effects should be manifested somewhere on the transitions, not on the steady states. Fowler describes coarticulation as extending on the whole unstressed vowel (1981). The data from Arabic used in this study will be analyzed and tested for significance in relation to these issues. In particular, the effects of V_1 and V_2 on the steady state of one another in V_1CV_2 utterances and the effects of pharyngealization will be emphasized. It is expected that pharyngealization, a feature which is a combination of raising the tongue dorsum towards the velum and retracting it towards the posterior pharyngeal wall, will lower the frequency of the second and third formant steady states for all adjacent vowels.

2. Experiment

2.1. Stimuli and Materials: A list of 72 utterances was constructed. A few of these utterances are actual words in Arabic and the majority are nonsensical sequences. The list contained the long vowels /i/, /a/ and /u/ in initial and final position of the sequences and the consonants /t/, /d/, /s/, /ð/ and their pharyngealized counterparts. The total of sequences were calculated in the form three preceding vowels X eight consonants X three following vowels = 72. This list includes all possible combinations of vowels and eight consonants included in the study.

2.2. Subjects: The subjects are two graduate students at The Ohio State University who are native speakers of Levantine Arabic. One of them will be referred to as LH, who is also the author of this paper, and the other as MA.

2.3. Procedure and Design: All VCV sequences were written in Arabic script on 3x5 inch cards. The cards were numbered and randomized in an attempt to eliminate any possible practice effects. Each of the 72 types was read five times by each subject with the following constraint on ordering: no token could be repeated until each of the other 71 tokens had been repeated at least once for any given cycle. The data were recorded in an anechoic chamber in the Linguistics Laboratory at The Ohio State University on a four track reel-to-reel recorder. The recording was then transferred to a cassette in a way that preserved the quality of the original recording. Subjects were instructed to read in a monotone and with phonemically long vowels. Wide-band spectrograms for all the tokens were then projected on the screen of a Voice ID RT 1000 machine used for spectrographic analysis in the Speech and Hearing Department at The Ohio State University. Zooming was carried out to enlarge spectrograms for the best possible projection for all the tokens. Measurements of frequency for the second formant were taken at four points in the V_1CV_2 sequences:

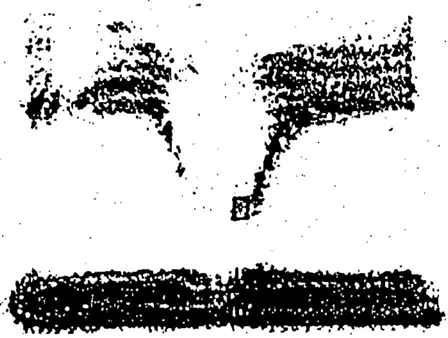
(1) The steady state of V_1
(2) The end of the transition of V_1 (into C)
(3) The beginning of the transition of V_2 (out of C)
(4) The steady state of V_2

NS: 256 SD: 4064 mS FM: 5616 Hz TA: 912
BW: 150 Hz SF: 16000 Hz Fm: 0 Hz TB: 1920

928 mS 2254 mS 1326 mS
0 Hz • 2109 Hz D: 2109 Hz
12 dB 27 dB 15 dB

Fig. 3: Cursor placement at the center of the steady state of V2 in the sequence /idi/ (speaker MA)

NS: 256 SD: 4064 mS FM: 3312 Hz TA: 160
BW: 150 Hz SF: 16000 Hz Fm: 0 Hz TB: 1552



174 mS 1500 mS 1326 mS
0 Hz • 1218 Hz D: 1218 Hz
3 dB 15 dB 12 dB

Fig. 4: Cursor placement at the beginning of the transition of V2 in the sequence /iði (speaker LH).

The measurements were taken by moving a cursor to the center of the formant and recording the frequency given automatically by the machine at the bottom of the screen. Figure 3 shows an example of placing the cursor at the steady state of V_2 and Figure 4 shows it at the beginning of the transition for V_2.

It is worth noting that the final decision of writing the utterances in isolation rather than having them in a frame sentence was based on three pilot studies. The outcomes of these studies have shown that other intervening factors in speech production such as adjacent phones, rate of speech, and stress placement resulting from using the frame sentence contribute uncontrollably to coarticulation. Therefore, the researcher became convinced that the best method of conducting the experiment is to have the utterances recorded in isolation as did Öhman.

3. Results

Figures 5 to 10 show mean and standard deviation values of steady state (top) and transition endpoint (bottom) for each vowel when the preceding or following vowel is /i/ versus /u/, divided by speaker (dashed lines for LH versus solid lines for MA), by intervening consonant feature (squares for pharyngealized versus circles for nonpharyngealized), and by consonant class (fricative to the left and stops to the right). The four graphs in each figure have been labelled A, B, C, and D to facilitate the process of reference in the explanation section.

The six figures have been grouped into two sets depending on whether V-to-V coarticulation is anticipatory or carryover. The first section shows the anticipatory effects and the second section shows the carryover effects. V-to-V coarticulation would be evident in the graphs as a significant difference between the connected /i/-context and the /u/-context means, with /u/-context means having lower frequencies than /i/-context means.

3.1. Anticipatory V-to-V Coarticulation

The first three figures show the effects of V_2 on V_1 in V_1CV_2 sequences. These effects are presented according to the preceding vowels in the order of /i/, /a/, and /u/.

3.1.1. ANTICIPATORY COARTICULATORY EFFECTS ON /i/

Figure 5 displays the anticipatory effects on /i/. None of the four graphs shows any significant V-to-V coarticulatory effects across pharyngealized consonants. Indeed, the top two graphs (A and B) show a tendency for the second formant to systematically have higher frequencies when the following vowel is /u/ than when it is /i/. The top two graphs also show a tendency for the second formant frequency to decrease across nonpharyngealized intervocalic fricatives for both speakers and across stops for MA when the following vowel is /u/. This decrease, however, is not statistically significant (F = .80, P < .3778 for fricatives) and (F = .32, P < .5765 for stops), so we cannot claim that there are coarticulatory effects on the steady state of /i/. The lower two graphs (C and D) show that pharyngealized consonants block coarticulation. Nonpharyngealized consonants, on the other hand, manifest two types of behavior that depend on the intervocalic consonant class. Stops block coarticulation while fricatives show significant effects (F = 12.51, P <.01). This conclusion conflicts with that of Öhman who reported that stops in Swedish and English permit V-to-V coarticulation and fricatives in both languages block it. One explanation for this contradiction is to assume that V-to-V coarticulation can be a language-particular phenomenon. It is not necessary to believe that what applies to one or two languages should apply to the rest of the languages in the world.

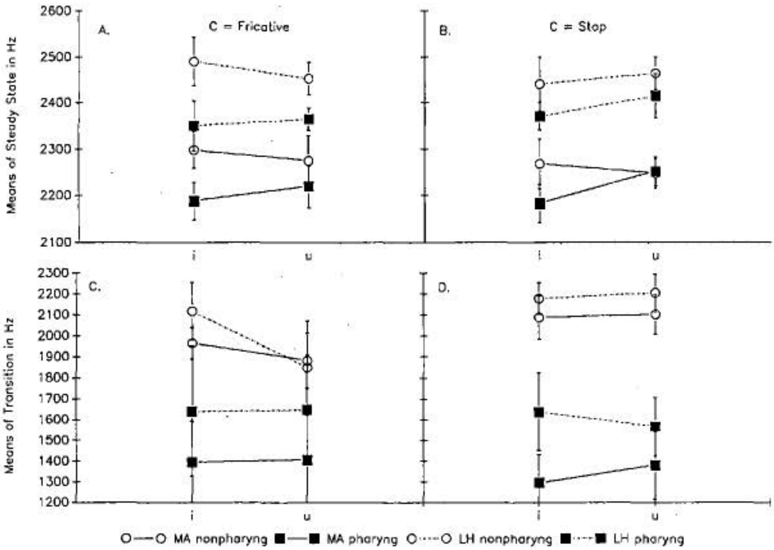


Fig. 5: Anticipatory effects of V2 on /i/ as V1.

3.1.2. Anticipatory coarticulatory effects on /a/

Figure 6 displays the anticipatory coarticulatory effects on /a/. The figure shows significant coarticulatory effects on the transitions of /a/ across the two speakers when the intervocalic consonant is nonpharyngealized (F = 38.60, P < 0.001 for fricatives and F = 57.82, P < 0.001 for stops). By contrast, there are no coarticulatory effects on the transition of /a/ across pharyngealized consonants (see

Graphs C and D). The feature pharyngealization plays a similar role in blocking coarticulation between the steady states. Pharyngealization, however, does not seem to be the only factor that determines whether coarticulation should or should not occur. Other factors, especially the speaker, become important for coarticulation in this case. The speaker MA, for example, shows significant coarticulatory effects across intervocalic fricatives and stops ($F = 40.69$, $P < 0.001$). LH, on the other hand, shows coarticulatory effects across intervocalic stops only.

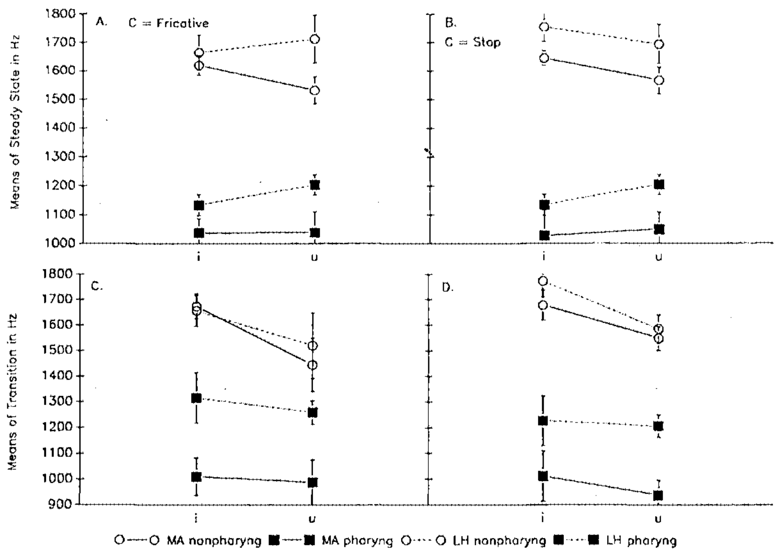


Fig. 6: Anticipatory effects of V_2 on /a/ as V_1.

3.1.3. ANTICIPATORY COARTICULATORY EFFECTS ON /u/

Figure 7 displays the anticipatory effects on /u/. No systematic coarticulatory patterning can be elicited from Figure 7; none of the four graphs included in the figure shows significant coarticulatory effects. This outcome supports neither Keating nor Fowler. It shows that V-to-V coarticulation does not always exist in VCV utterances as Fowler claims. It also shows that coarticulation cannot always be attributed to the existence or absence of the secondary articulation feature pharyngealization as Keating claims; rather it can be the intrinsic feature of the vowel being studied that determines whether coarticulation should occur or not. Some vowels have shown to be more resistant than others to V-to-V coarticulation. /a/ seems to be the vowel most tolerant of V-to-V coarticulation, /i/ is less tolerant, and /u/ is the least tolerant of coarticulation. This might be explained by the fact that /a/ is the only low vowel in Arabic. Therefore, it has more room for allophonic variation than either /i/ or /u/.

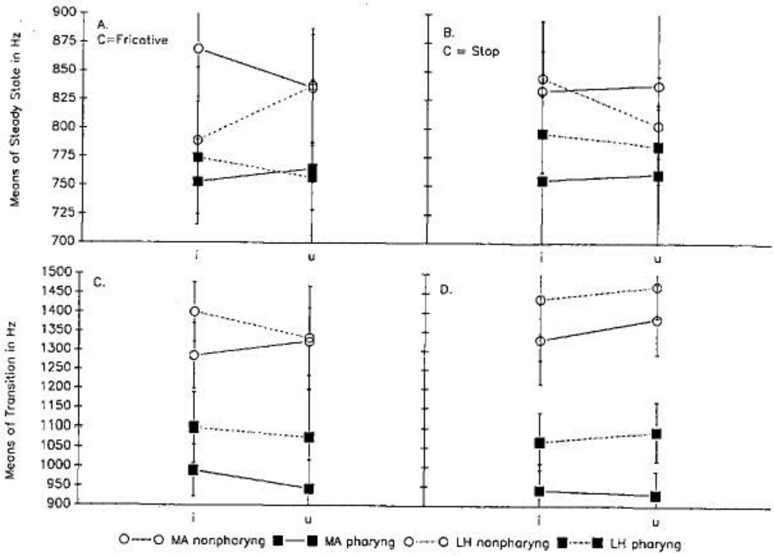


Fig. 7: Anticipatory effects of V2 on /u/ as V1.

3.2. Carryover V-to-V Coarticulation

Figures 8-10 display the effects of V_1 on V_2 in V_1CV_2 sequences. The effects are arranged according to the quality of the following vowels in the order of /i/, /a/, and /u/.

3.2.1. CARRYOVER COARTICULATORY EFFECTS ON /i/

Figure 8 displays the carryover coarticulatory effects on /i/. Figure 8 confirms Keating's prediction in two aspects: (1) only consonants with no vowel feature [+back], nonpharyngealized consonants, allow V-to-V coarticulation, and (2) the coarticulatory effects can be restricted to the transitions of vowels for some speakers. The top two graphs (A and B), which display the carryover coarticulatory effects on the steady state of /i/, show significant effects for the speaker LH ($F = 7.37$, $P < 0.001$), but no significant effects for the speaker MA. The lower two graphs (C and D), which display the carryover coarticulatory effects on the transition of /i/, show significant coarticulatory effects ($F = 20.38$, $P < .001$ for fricatives and $F = 25.18$, $P = < .001$ for stops) on /i/ when the intervocalic consonants are nonpharyngealized. By contrast, their pharyngealized counterparts do not show significant effects. This conclusion argues against Fowler who claims that intervocalic consonants, regardless of what features they may have, should not block coarticulation. It also shows that plain (nonpharyngealized) fricatives permit V-to-V coarticulation in Arabic, unlike their "counterparts" in English and Swedish, as it has been reported by Öhman.

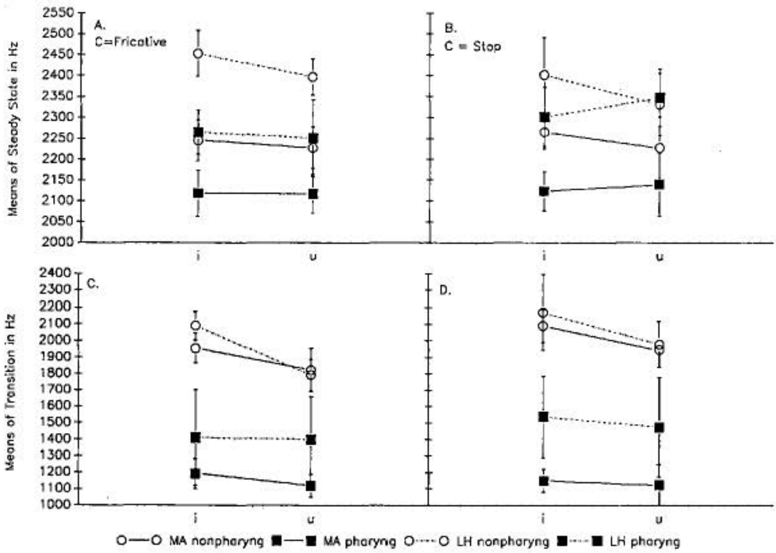


Fig. 8: Carryover effects of V_1 on /i/ as V_2.

3.2.2. CARRYOVER COARTICULATORY EFFECTS ON /a/

Figure 9 summarizes the carryover coarticulatory effects on /a/. Similar to Figure 6, coarticulatory effects occur systematically on the transition of /a/ so long as the intervocalic consonant is nonpharyngealized. Both speakers exhibit significant coarticulatory effects across nonpharyngealized intervocalic stops and fricatives at $F = 21.74$, $P < 0.001$ for stops and $F = 15.82$, $P < 0.001$ for fricatives (see Graphs C and D). In the meantime, and unlike any other figure that has been discussed so far, Figure 9 shows a case of V-to-V coarticulation across pharyngealized consonants. One speaker, LH, shows significant coarticulatory effects on both transitions ($F = 63.60$, $P < 0.001$) and steady state ($F = 34.01$, $P < 0.001$) of /a/.

The other speaker, MA, by contrast, does not show similar coarticulatory effects on either.

Coarticulatory effects on the steady state seem to be dependent on the speaker. LH, on the one hand, shows significant and systematic coarticulatory effects across all intervocalic consonants; namely, across nonpharyngealized stops, nonpharyngealized fricatives, pharyngealized stops, and pharyngealized fricatives. MA, on the other hand, shows a tendency for coarticulation to occur across nonpharyngealized consonants, but no coarticulation whatsoever across pharyngealized ones.

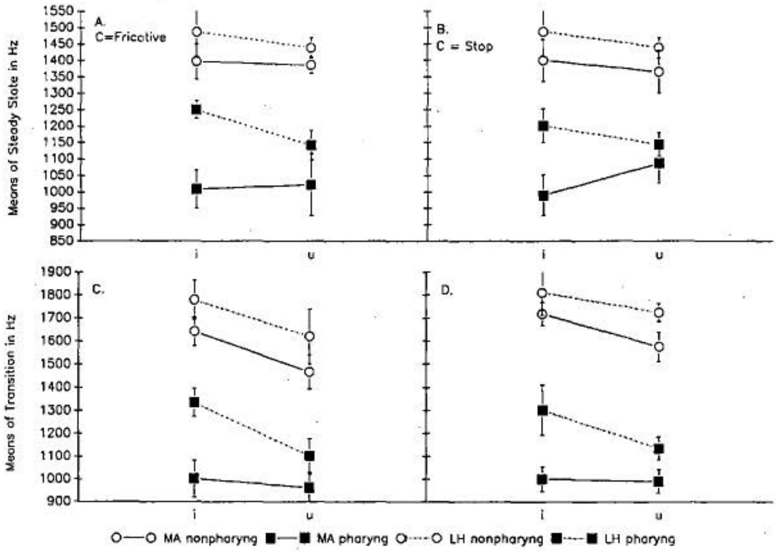


Fig. 9: Carryover effects of V_1 on /a/ as V_2.

Several conclusions can be drawn from this figure:

(1) Neither of the two models sketched above (Keating's and Fowler's), which were the main incentive to this study, adequately accounts for all cases of V-to-V coarticulation. Keating's model falls short of accounting for the coarticulatory effects across pharyngealized consonants as is the case with LH, and Fowler's model cannot account for the absence of coarticulation across pharyngealized consonants in the case of MA.

(2) The speaker has proven to be an important factor in V-to-V coarticulation. LH shows coarticulatory effects in all environments given in Figure 9. MA, by contrast, shows coarticulatory effects on the transitions of /a/ across nonpharyngealized consonants only.

(3) The direction of coarticulation (carryover versus anticipatory) seems to induce different coarticulatory patterns. The comparison between Figure 2, which summarizes anticipatory coarticulatory effects on /a/, and Figure 9, which summarizes carryover coarticulatory effects on /a/, shows that V-to-V coarticulation is likely to occur across pharyngealized consonants as a carryover case but not as an anticipatory one.

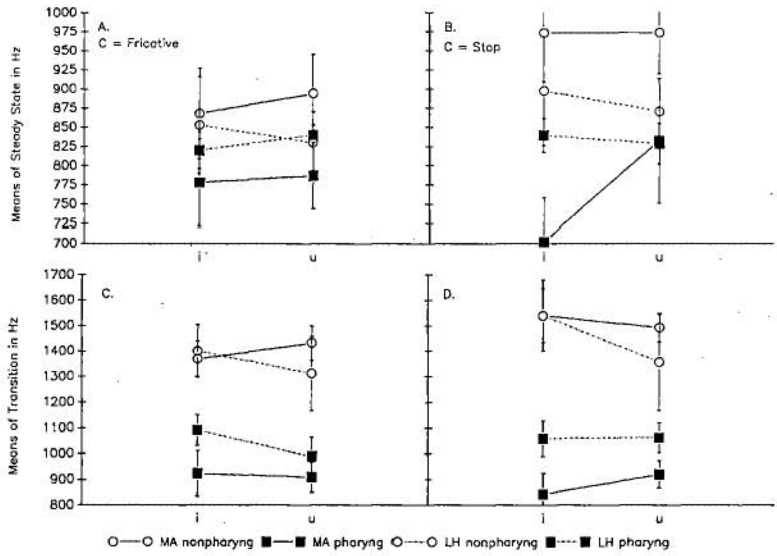


Fig. 10: Carryover effects of V_1 on /u/ as V_2.

3.2.3. CARRYOVER COARTICULATORY EFFECTS ON /u/

Figure 10 summarizes the carryover coarticulatory effects on /u/. Similar to Figure 7, Figure 10 does not show any systematic coarticulatory effects across the two speakers. It confirms the conclusion that /u/ does not tolerate V-to-V coarticulation and consequently acts as the vowel in Arabic most resistant to coarticulation. One speaker, LH, however, exhibits anomalously significant coarticulatory effects ($F = 8.59$, $P < 0.0057$) on the transition of /u/ in nonpharyngealized environments. The same speaker exhibits coarticulatory carryover effects on the transition and the steady state of the other two vowels in nonpharyngealized environments (see Figures 8, 9). He even sometimes exhibits carryover effects in pharyngealized environments as is the case with /a/ (see Figure 9). He does not, however, show similar systematic anticipatory coarticulatory effects. This outcome implies that there might be some association between some speakers or dialects (see **Discussion and Conclusions** for an explanation on dialectal differences) and the direction of coarticulation.

In general, the speakers in this study, especially LH, tend to show more carryover coarticulatory effects than anticipatory ones. Similar conclusions where greater carryover than anticipatory coarticulation occurs have been reported for English (Fowler 1981).

The outcome in this figure and other figures indicates that V-to-V coarticulation can be vowel-dependent. Figures 6 and 9 show significant coarticulatory effects on the transitions of /a/ across all nonpharyngealized intervocalic consonants and across both speakers (see Graphs C and D in Figures 6 and 9). The vowels /i/, as manifested in Figures 5 and 8, and /u/, as it is presented in Figures 7 and 10, do not show similar systematic coarticulatory effects on their transitions (see Graph D in Figure 5 and Graphs C and D in Figures 7 and 10).

4. Discussion and Conclusions

Data reported in the Results section have shown that V-to-V coarticulation in Arabic is not as simple as either of the two models predicts it to be. It cannot be assumed that coarticulation should occur in all VCV utterances, as Fowler's model implies, without taking into account all intervening factors in speech production; nor can coarticulation be solely attributed to the existence or absence of one feature in Arabic (pharyngealization), as Keating claims. Instead several other factors have been proven to be directly related and detrimental to coarticulation.

A new approach is needed to account for such a complicated phenomenon. First, I propose that V-to-V coarticulation is dependent on vowel height and the number of vowels a language has. High vowels, especially back ones, are more resistant to V-to-V coarticulation than low ones. Also the degree of V-to-V coarticulation increases as the number of vowels in a language decreases and vice versa. This assumption accounts for the fact that V-to-V coarticulation occurs more frequently across non-pharyngealized consonants than across pharyngealized ones. Pharyngealization, a secondary articulation vocalic feature, does not only retract the tongue root towards the posterior pharyngeal wall, but it also raises it towards the velum. Figure 11, adopted from Ali and Daniloff (1972), shows the tongue movement during the production of pharyngealized /ţ/ and non-pharyngealized /t/. The figure presents a sample that is based on a cinefluorographic investigation of pharyngealized and non-pharyngealized consonants' articulation. With pharyngealized consonants being [+back] and [+high], it becomes more likely that V-to-V coarticulation will be blocked. Therefore, none of the figures 5 through 10 shows systematic V-to-V coarticulation across pharyngealized consonants.

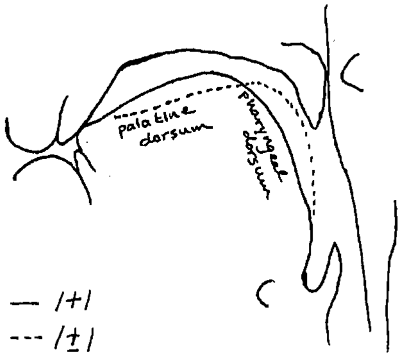


Fig. 11: A sample cine frame showing differences (in mm) in tongue position for contrasting pharyngealized /ṭ/ with non-pharyngealized /t/.

This assumption also accounts for the fact that the three vowels of Arabic have shown various degrees of tolerance towards V-to-V coarticulation. /a/, being non-high and the only low vowel in Arabic, creates the perfect environment for coarticulation. There is enough room for allophonic variation and there is no vowel height to resist coarticulation. Thus, Figures 6 and 9 show the highest degree of tolerance for V-to-V coarticulation. There are systematic coarticulatory effects on all transitions and most steady states across non-pharyngealized consonants. There are also carryover coarticulatory effects for LH across pharyngealized consonants as well. /u/, being high and back vowel, is the most resistant to coarticulation. No systematic coarticulatory effects across the two speakers can be inferred from Figures 7 and 10. /i/, being also a high front vowel, has more tolerance than /u/ and less than /a/.

Second, the speaker has been proven to be an essential factor in coarticulation. The two speakers participating in this experiment do not always show similar coarticulatory effects. In particular, speaker LH has shown coarticulatory effects in a wider range of environments than MA. This observation can be clearly seen in Figure 9 where LH coarticulates across pharyngealized and nonpharyngealized consonants while MA coarticulates across nonpharyngealized consonants only, in Figure 10 where LH shows significant coarticulatory effects on the transitions of /u/ while MA does not show similar effects, and in Figure 8 in which LH shows coarticulatory effects on the steady state of /i/ while MA does not. The only anomalous case exists in Figure 6 where the speaker MA shows coarticulatory effects on the steady state of /a/ and LH does not.

This difference between the two speakers can be attributed to the rate of speech production that has been developed by each of the speakers and the dialectal differences that exist between the two speakers. People who have developed a habit of speaking fairly fast are likely to coarticulate more than those who speak at a slower rate. Both speakers participating in this experiment have been noticed to have developed two different rates of speech production. The speaker LH has been noticed to speak faster than MA. This observation may account for the fact that he coarticulates in a wider range of environments than MA.

Meanwhile, though both subjects are native speakers of Levantine Arabic, each of them speaks a "subdialect" within Levantine Arabic that is slightly different from the other. MA speaks urban Levantine Arabic and LH speaks rural Levantine Arabic. The difference between the two subdialects may also account for the fact that LH coarticulates more than MA. In other words, it is likely that the patterns of coarticulation in rural Levantine Arabic are different from those of urban Levantine Arabic. Further studies are needed to confirm or refute this outcome.

Third, the direction of coarticulation has also been shown to be an important factor in V-to-V coarticulation in Arabic. Carryover effects tend to occur almost systematically on the transitions of all vowels across nonpharyngealized consonants. The only exception to this systematicity is the absence of coarticulatory effects on the transitions of /u/ as manifested by MA. Carryover effects also show on the transitions and the steady state of /a/ across pharyngealized consonants as well for the speaker LH.

Anticipatory effects, by contrast, are systematic across nonpharyngealized consonants on the transitions of /a/ only. No significant effects are manifested on the transitions of /u/ for either speaker in the same environment nor are there effects on the transitions of /i/ across nonpharyngealized stops. No significant effects are shown in any pharyngealized environment.

The reasons for the systematicity in the carryover direction versus the sporadicity in the anticipatory direction can be attributed to the stress patterns in two-long-vowel utterances and the phonological system of Arabic. Arabic places the primary stress on the first long vowel in these utterances and shortens the long vowel word finally. Thus, in actual production, V_1 in V_1CV_2 utterances is generally longer and more emphasized than V_2. Therefore, the likelihood for V_2 to coarticulate due to lack of emphasis and shortening is greater than that of V_1. Indeed, most non-native learners of Arabic perceive long vowels in word final position as /ə/. For example, the word /læ:/ meaning "no" is usually perceived as /lə/ (personal observation).

Like most studies in speech production, the results of this experiment are based on data obtained from a relatively small subject population. The findings are therefore far from conclusive. They, however, can serve as good starting points for examining a number of questions concerning V-to-V coarticulation in Arabic. Among these questions are:

(1) Do Arabic speakers show more systematic carryover coarticulation than anticipatory ones, as the present study reveals?

(2) Could there be some kind of priority scale which would classify some factors as more important than others in their effects on coarticulation? For example, the study reveals to me that vowel height is the most important factor in determining whether coarticulation in VCV utterances should occur or not; there are always coarticulatory effects on the transitions of /a/, less so on /i/ and /u/. The feature pharyngealization comes in second place; its presence blocks coarticulation in almost all cases, but its absence does not imply that coarticulation should occur. The speaker and possibly dialectal differences come in third place. Finally comes the intervocalic consonant class, though it has played a minimal role in this study, especially if we compare it to the role it played in Öhman's study (1966).

Acknowledgement

I wish to thank Mary Beckman for her assistance at all stages in writing this paper. Mary provided invaluable help in the fields of phonetics, computer use, and statistics. I would like also to express my thanks to Robert Fox who allowed me to use the RT 1000 spectrographic machine in the Speech and Hearing Department and Diane Hambrick who helped in editing the final draft of this paper.

Bibliography

Ali, Hassan Latif and R. G. Daniloff. (1972). "A contrastive cinefluorographic investigation of the articulation of emphatic-nonemphatic cognate consonants", *Studia Linguistica* **25**: 81-105.

Bonnot, J. F. (1977). "Recherche experimentale sur la nature des consonnes emphatiques de l'Arabe classique", *Travaux de l'Institut de Phonetique de Strasbourg* **9**: 47-88.

Card, Elizabeth Anne. (1983). *A phonetic and phonological study of Arabic emphasis*. Ph.D. dissertation, Cornell Univ. University Microfilms International.

Fowler, Carol A. (1981). "A relationship between coarticulation and compensatory shortening", *Phonetica* **38**: 35-50.

________. (1983). "Converging sources of evidence on spoken and perceived rhythms of speech: cyclic production of vowels in monosyllabic stress feet." *Journal of Experimental Psychology*, General. **112**: 386-412.

Gay, T. (1977). "Articulatory movement in VCV sequences", *JASA (Journal of the Acoustical Society of America)* **62**: 183-193.

Ghazeli, S. (1977). *Back consonants and back coarticulation in Arabic*, Ph. D. dissertation, The University of Texas at Austin.

Jakobson, R. (1962). "Mufaxxama, the 'emphatic' phonemes in Arabic", in *Selected Readings, Roman Jakobson* (Mouton and Co., The Hague), pp. 510-522.

Keating, Patricia A. (1985). "CV phonology, experimental phonetics, and coarticulation", *UCLA Working Papers in Phonetics* **62**: 1-13.

Manuel, S. Y. and R. A. Krakow. (1984). "Universal and language particular aspects of V-to-V coarticulation", Haskins Laboratories: *Status Reports on Speech Research* **SR-77/78**, 69-78.

Obrecht, D. H. (1961). *Effects of the second formant on the perception of velarization consonants in Lebanese Arabic.* Ph.D. dissertation, Univ. of Pennsylvania. On microfilm (from Penn.).

Öhman, S. E. G. (1966). "Coarticulation in VCV utterances: spectrographic measurement", *JASA* **39**: 151-168.

Purcell, Edward T. (1979). "Formant frequency patterns in Russian VCV utterances", *JASA* **66**: 1691-1702.

Recasens, Daniel. (1985). "Vowel-to-vowel coarticulation in Catalan VCV sequences", Haskins Laboratories: *Status Reports on Speech Research* **SR-81**: 181-204.

________. (1986). "An acoustic analysis of V-to-C and V-to-V: coarticulatory effects in Catalan and Spanish VCV sequences", Haskins Laboratories: *Status Report on Speech Research* **SR-86/87**: 71-86.